Integrated Studies of Oceanographic Processes and Shallow Water Acoustics in the South China Sea: Custom Climatology and Mid-Shelf Field Work

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http://www.whoi.edu/science/po/people/clinder/software_climo_xshelf.html
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LONG-TERM GOALS

Our long-term goal is to understand shelfbreak processes in the South China Sea including the Kuroshio Intrusion and their impact on shallow water acoustic propagation for low and mid-frequency acoustics.

OBJECTIVES

The scientific objectives are to obtain climatologies of the continental shelf and slope regions around Taiwan as well as to continue analysis of hydrographic data collected during a joint Oceanographic-Acoustics cruise during April, 2005.

APPROACH

We have developed a new methodology for computing climatologies for shelfbreak and continental shelf regions where the cross-shelf scales of variability tend to be small and the bathymetry may be complicated and create artifacts using traditional rectangular grid techniques. We average in the alongshelf direction and map the fields relative to the isobath at the shelfbreak (or other significant isobath). By collapsing the data into a cross-shelf section we retain the high resolution (comparable to the baroclinic Rossby radius) from the alongshelf averaging. We also calculate plan view maps for fixed depth ranges to see the spatial structure of variability to identify "hot spots" of enhanced variability. The peaks in variability from the planview maps can be related to topography, river

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outflows, or other forcing mechanisms. One goal of this study is to relate seasonal mean structures to the variety of Kuroshio Intrusions previously identified by Caruso et al. (2005).

We are presently analyzing data collected from the joint cruise with Taiwanese scientists in April, 2005, over the continental shelf. We did a long CTD section extending onshore over the continental shelf to the 30 m isobath. We collected high-resolution hydrographic data from a towed Scanfish vehicle as well as a short duration mooring array of temperature sensors between the 75 m and 90 m isobaths. We have been collaborating with P. Abbot and C. Emerson of OASIS Inc. to relate oceanographic processes to changes in transmission loss measured from a mobile acoustic source and drifting sonobuoys. We have also been collaborating with L. St. Laurent of Florida State University to examine the temporal variability of the internal waves and tides over the outer shelf to his observations of turbulent dissipation and microstructure.

During the past year, we have been working with a visiting Ph.D. candidate from National Taiwan University, Jen-Hua Tai, on a climatology of the central basin of the South China Sea. He also has worked on a two-layer stability model of the Kuroshio in Luzon Strait. As part of this effort, we worked with Dr. Joe Wang of National Taiwan University on a cruise in August, 2007

WORK COMPLETED

We have completed a climatology of the continental shelves surrounding Taiwan (Linder et al., 2006). The technical report contains both planview maps for each season in four different regions of the continental shelf and upper slope surrounding Taiwan as well as averaged cross-shelf sections. The fields are contained within the technical report. We are presently working on a manuscript describing the results. We have also worked with scientists at OASIS Inc. to relate shifts in the patterns of transmission loss to the internal tides over the outer shelf (Emerson et al., 2007). J.-H. Tai has completed the climatology of the central basin of the South China Sea including summer and winter monsoon periods, as well as the two-layer stability model of the Kuroshio over the ridge topography.

During August, 2007, we did a short cruise in Luzon Strait to study the structure of the Kuroshio and its relation to the underlying bathymetry. While the cruise was shortened due to several typhoons, we were able to complete four cross-frontal SeaSoar transects. Due to a severe swell generated by multiple typhoons, we were forced to continue our studies southeast of Taiwan, where we were able to examine the flow as the Kuroshio passed over a sill.

RESULTS

We have completed the climatology of the continental shelves and slope surrounding Taiwan. An example for the northern South China Sea appears in Figure 1, showing the mean density field for summer. The buoyant surface water near the shelfbreak is associated with low salinity water carried in the mean southwestward flow. The standard deviation of the density field shows peaks in the surface and over the upper slope (Figure 2). While the climatology does not allow one to determine exactly which physical processes are setting the spatial structure of the variability, it does provide guidance for the expected locations of “hotspots” of variability and can be compared with model-generated standard deviation fields. Similar sections for temperature, salinity, density, and soundspeed have been calculated for the northern South China Sea, Taiwan Strait, Kuroshio east of Taiwan, and East China Sea northeast of Taiwan. We are presently referencing the geostrophic shears computed

from these fields with spatially-averaged shipboard Acoustic Doppler Current Profiler fields to calculate relative and potential vorticity mean fields near the shelfbreak. This work is in collaboration with J.-H. Tai and Professor David Tang of National Taiwan University.

J.-H. Tai has computed stability characteristics of the Kuroshio over two-ridge topography. Using a model based on previous work by Barth (1989), he has found that the most unstable wavelength for instabilities of the Kuroshio for a flat bottom is 380 km versus 327 km for ridge topography. The presence of the ridge increases the phase velocity of the most unstable wave from 32 to 46 cm/s so that the time for a wave to pass across Luzon Strait decreases from 8 days in the flat bottom case to 5.6 days in the ridge case. The presence of the ridge also introduces greater phase shifts near the crest of the wave, and intensifies the flow in the lower layer over the ridge crest. A plan view of the wave structure for the most unstable wave with ridge topography appears in Figure 3. This work was done while Tai was a visiting student at WHOI, working with Gawarkiewicz.

During early August, 2007, Gawarkiewicz participated in a cruise to examine the structure of the Kuroshio over the ridges in Luzon Strait using the National Taiwan University SeaSoar. The cruise was in collaboration with Professor Joe Wang of NTU. While the cruise was heavily impacted by two typhoons, we were able to collect four sections across the Kuroshio (Figure 4) in Luzon Strait as well as some data southeast of Taiwan. A particularly interesting feature was the presence of a thin surface layer of low salinity water southeast of Taiwan from runoff associated with the typhoons.

IMPACT/APPLICATIONS

We have used the climatology of the Taiwan continental shelves for a number of different issues. This has helped us in our ongoing study of the inter-annual variability in the shelfbreak region of the northeast South China Sea. We were able to assist B. Reeder of the Naval Postgraduate School to develop his hydrographic sampling scheme this past April for his acoustic propagation studies. The climatology which J.-H. Tai developed for the central basin was then used to determine the parameters for the basic state of the stability model. Eventually, the stability results will be related to the modulation of internal wave propagation by the mesoscale fields in the South China Sea.

We are working with L. St. Laurent of Florida State University to provide comparisons from the April, 2005 field data to predictions of remote trans-basin internal wave packets provided by C. Jackson. The data set is interesting because of the deep surface mixed layer relative to the strongly stratified conditions during the ASIAEX experiment in 2001.

RELATED PROJECTS

Much of the work in this project has been directly related to planning and analysis for the DRI Quantifying, Predicting, and Exploiting Uncertainty. We have used the climatology to examine the spatial structure of the variability near the shelfbreak northeast of Taiwan. Results of the acoustic propagation studies have been used to help plan the acoustic component of the DRI as well.

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Emerson, C., P. Abbot, C. Gedney, G. Gawarkiewicz, C.-S. Chiu, C.-F. Chen, and R.-C. Wei, 2007: Acoustic propagation observations in the shallow South China Sea. Proceedings, Underwater Acoustics Measurements: Technologies and Results, Crete, Greece. [Published, Refereed]

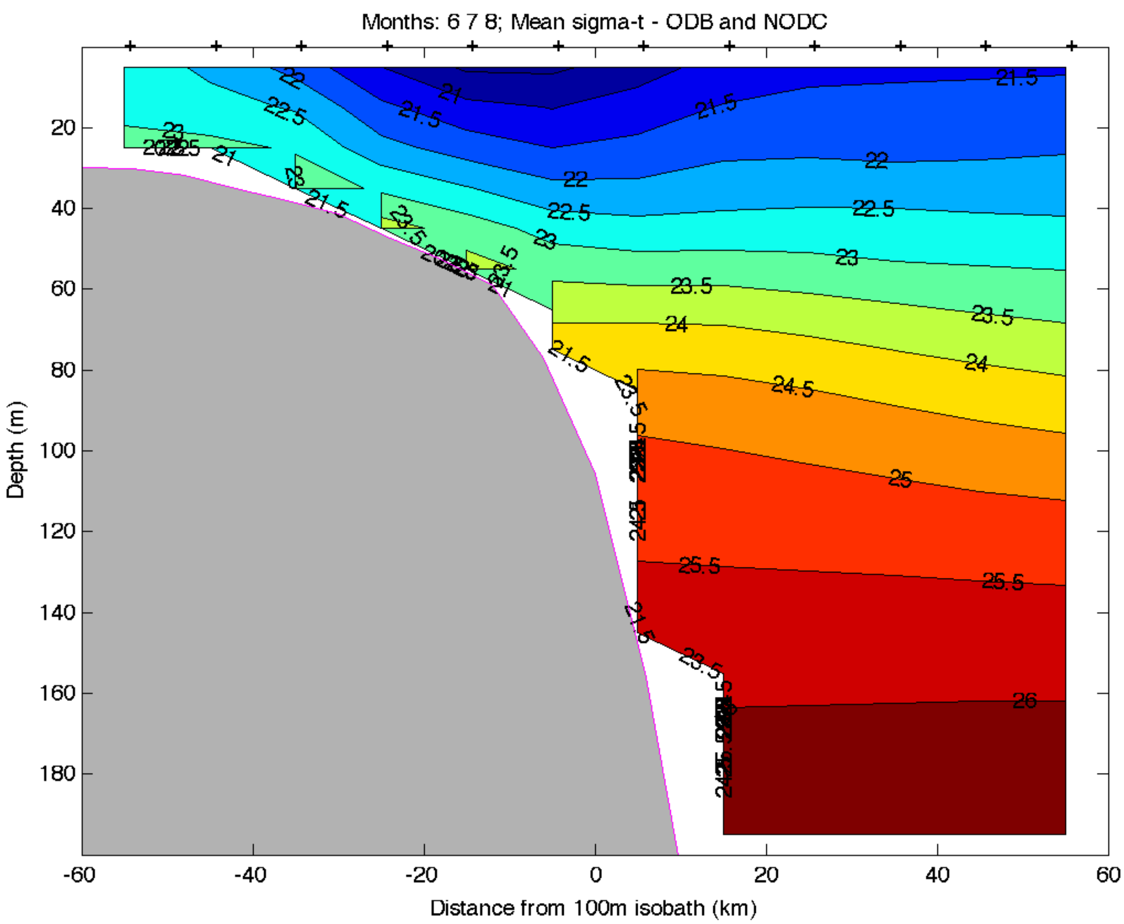

__Figure 1. A mean section of density at the shelfbreak in the northeastern South China Sea based on data from the Taiwanese historical hydrographic data base. The cross-shelf spacing of the bins is shown by the asterisks at the surface. This is for the average summer conditions, which goes from June through August, corresponding to the summer monsoon. Note the pool of surface buoyant water which sits at the shelfbreak,__

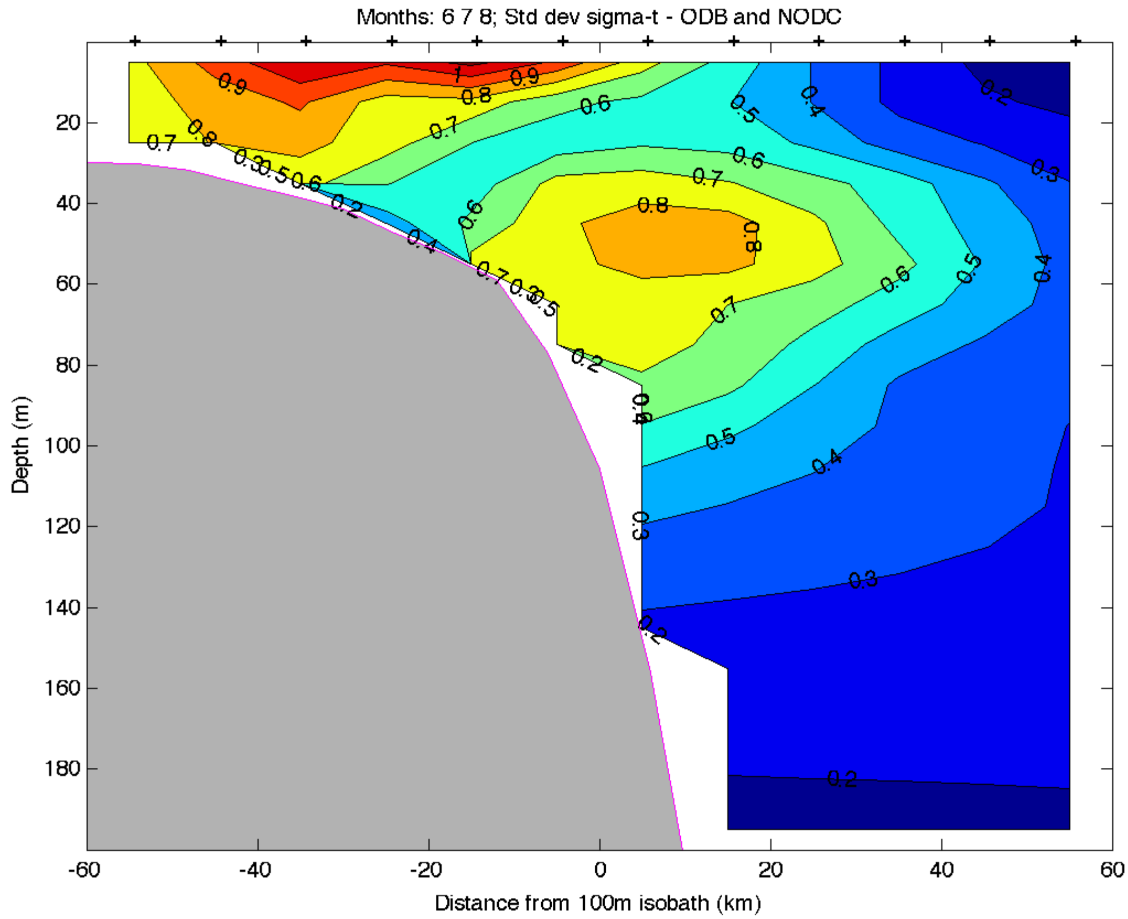

Figure 2. The standard deviation of density for the summer near the shelfbreak in the northeastern South China Sea. Note the largest values near the surface, just shoreward of the shelfbreak, and also at mid-depth (50 m) over the upper slope just seaward of the shelfbreak.

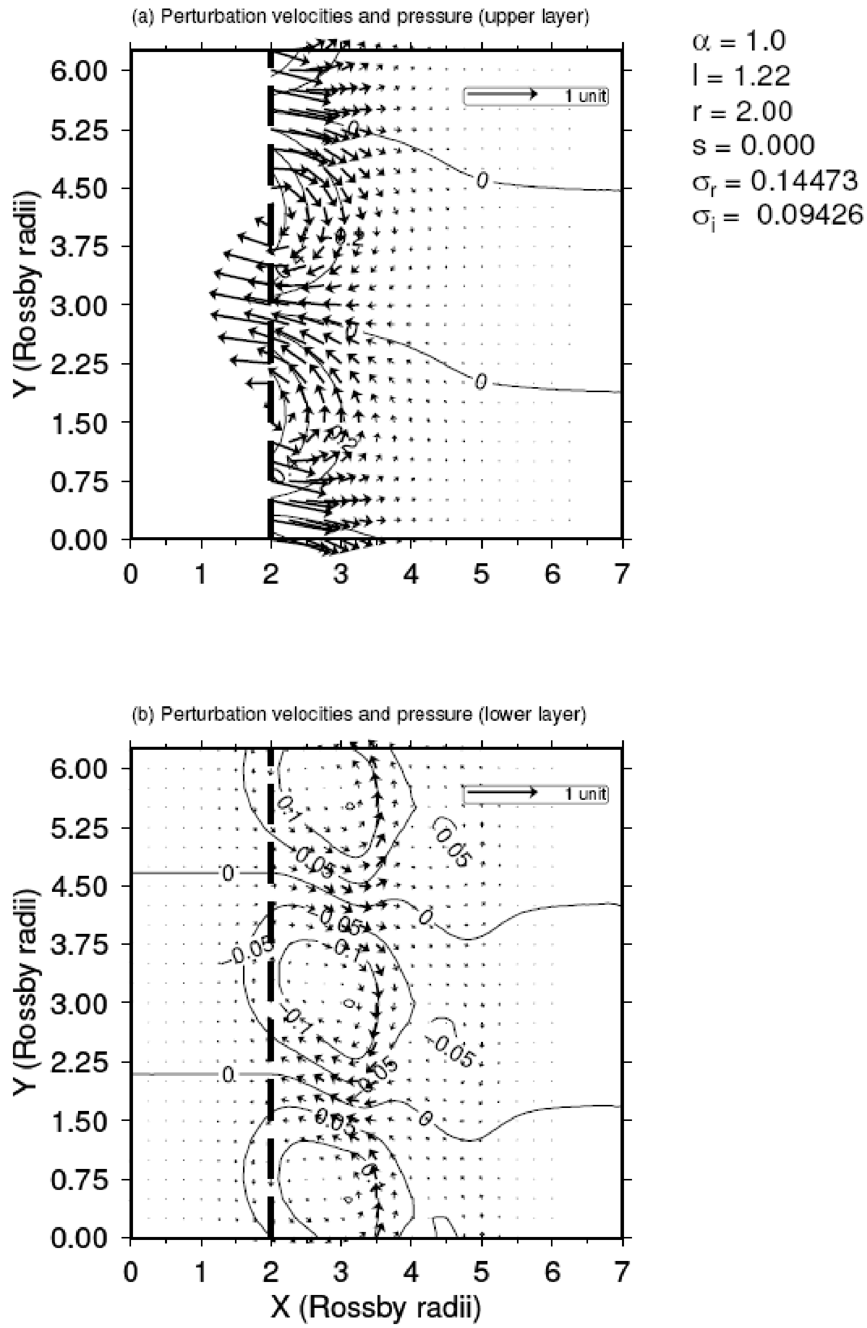

Figure 3. Plan views of a two layer model of instability of the Kuroshio for the upper layer (upper panel) and lower layer (lower panel) showing the perturbation pressures (contours) and perturbation velocities (arrows). The along-front and cross-front dimensions are scaled by the Rossby radius, which is 64 km.

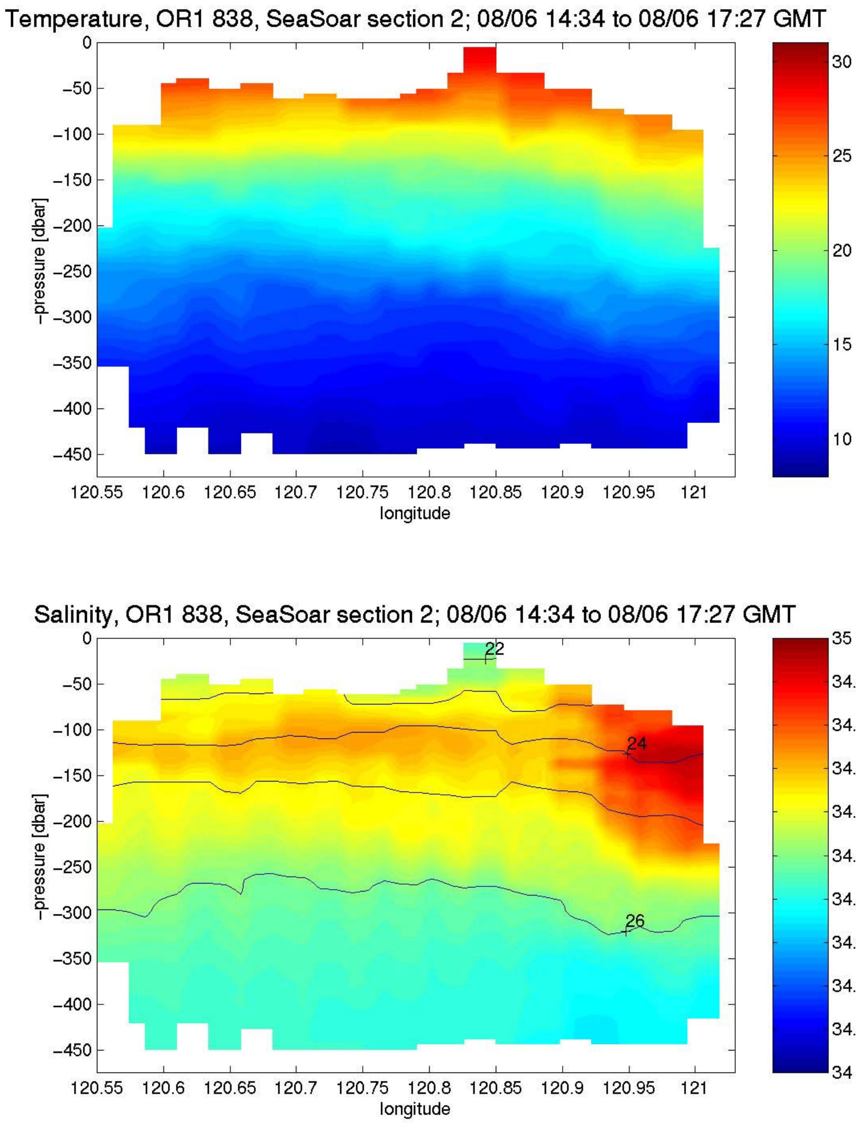

Figure 4. A SeaSoar section of the Kuroshio in the center of Luzon Strait. The upper panel shows potential temperature and the lower panel shows the salinity. Note the salinity maximum at 150 m depth.